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HISTORY OF ASTRONOMY SECTION

Copernicus and Astronomy: Continuity, Reform, and Dissemination

12–15.09.2023

NCU Faculty of Economic Sciences and Management

Gagarina 13a, 87-100 Toruń

12 September (Tuesday)

PTOLEMAIC AND ALFONSINE HERITAGE

PLENARY LECTURE: 09.30-10.30

The Genius of Nicholas Copernicus: An Islamic Perspective

F. Jamil Ragep, Institute of Islamic Studies, McGill University, Canada (Professor Emeritus)

Among the many puzzles posed by Copernicus and his new system is: why was a heliocentric solution needed? Of course, there have been any number of answers to this question, but in this lecture, I wish to look at the problem from the perspective of post-classical Islamic intellectual history. Whether one believes that Copernicus "borrowed" the models of his predecessor Ibn al-Shāṭir (Damascus, 14th c.) or reinvented them on his own, the fact remains that Ibn al-Shāṭīr's *geocentric* system brilliantly resolved the problem that Copernicus tells us in the *Commentariolus* was his main motivation, namely the irregularities brought about by Ptolemy's equant. But then why did Copernicus feel the need to go beyond Ibn al-Shāṭīr's geocentric solution and offer a much more problematic heliocentric one? Rather than try to provide yet another opinion regarding Copernicus's motivation, I will approach the problem from the perspective of late medieval Islamic astronomers and theologians, offering some conjectures about how they might have viewed Copernicus's extraordinary, and seemingly unnecessary, departure from classical astronomy and cosmology.

SESSION 1: 10.30-11.30

Islamic Astronomical Handbooks with Tables (*Zījes*) and their Transmission to Medieval Europe

Benno van Dalen, Ptolemaeus Arabus et Latinus – Bayerische Akademie der Wissenschaften, Germany

This presentation will give an overview of Arabic and Persian *zīj*es, one of the most important categories of Islamic astronomical literature. I will briefly discuss their origin in, on the one hand, Indian and Sasanian-Persian sources and, on the other, Ptolemy's *Almagest* and *Handy Tables*. I will give an impression of the more than 200 Arabic and Persian *zīj*es that were written between the years 800 and 1800 and the observational programmes that were carried out in various parts of the Islamic world in order to update the most important parameters underlying Ptolemy's planetary models. Finally, I will discuss the works that were most relevant for the development of astronomical table sets in medieval Europe, namely al-Khwārizmī's *Sindhind Zīj* and al-Battānī's *Ṣābiʾ Zīj*, which formed the basis of the *Toledan Tables*.

Al-Farghani's *Elements of Astronomy*: A Classified Account of Planetary Motions

Razieh S. Mousavi, Max Planck Institute for the History of Science, Humboldt University of Berlin, Germany

This paper aims to present a snapshot of my recently submitted dissertation at Humboldt University of Berlin in which I have studied the Arabic astronomical text entitled *Elements of Astronomy* written by Aḥmad b. Muḥammad al-Farghānī in around 860 CE. Whether viewed as a simple summary, a paraphrase, or an innovative reworking of Claudius Ptolemy's *Almagest*, this text fascinated medieval scholars in the Islamic world and beyond through its Latin and Hebrew translations. In my research, I have established the interaction between astronomical knowledge and literary dynamics in the ninth century that shaped al-Farghānī's peculiar narration of Ptolemaic astronomy. I also emphasize the overlap between medieval astronomy and medicine that is highlighted in the *Elements of Astronomy*, as well as the traces of literary techniques from Greek medical works employed by al-Farghānī in his text.

The correlation between astronomy and medicine in the early Islamic centuries has not sufficiently been examined despite the endorsement of the role of astrology in medical knowledge. I elaborate on this by drawing attention to the similarities between al-Farghānī's structural presentation of planetary motions and classification methods from the so-called *Summaria Alexandrinorum* (*Alexandrian Summaries*) of Hippocratic-Galenic medicine. This study illustrates for the first time the literary reasons behind the questionable naming of the *Elements of Astronomy* in Arabic, i.e., *Jawāmi*ʿ, which was rarely used for an astronomical text before him. Connecting these themes has led me to believe that al-Farghani's intention to provide a teaching manual of Ptolemaic astronomy, as well as his appreciation of the common ground of astronomy and medicine, encouraged him to utilize organizing principles in medical texts in his book on Ptolemy's *Almagest*.

SESSION 2: 12.00-14.00

Pre-Copernican Views of the Earth vis-à-vis Natural Philosophy

Fateme Savadi, Institute of Islamic Studies, McGill University, Canada

Late antique and medieval scholars showed various degrees of engagement with natural philosophy in their descriptions of the shape of the Earth and proofs of its sphericity and state of rest, as these issues were linked to natural philosophical properties of the elements.

There were two general ways of describing the shape of the Earth: 1) describing the Earth as a solid sphere, like in Ptolemy's *Almagest*; or 2) describing only its surface as spherical, like in Ptolemy's *Geography*. The first approach sometimes led to an inconsistency with the Aristotelian concentric order of the elements. The second approach was probably taken to circumvent this natural philosophical issue and to avoid related issues, such as the natural loci of the elements.

Another case of tension with natural philosophy was the land-water relation on the surface of the Earth. It was generally accepted that one-fourth of the surface of the Earth is land and the rest is covered by water, following from a natural philosophical doctrine about the proportional volumes of the elements.

According to this doctrine, which might have been formed within the late antique tradition of the Aristotelian *Meteorologica*, the elements must be balanced in their volumes. So, if water does not encompass three quarters of the Earth, then there would be much less water in the universe than there should be, compared to the volume of the earth. A thirteenth century scholar of the Islamic world, Quṭb al-Dīn al-Shīrāzī (d. 1311) explicitly rejected this doctrine and consequently rejected the prevalent view that three quarters of the surface of the Earth is water.

There are many other such cases of conflict with natural philosophy throughout the middle ages. In this talk, we study some of these tensions and the solutions scholars proposed for dealing with them, with a focus on the description of the Earth as a physical body.

Sizes, Distances, and Order: Celestial Reckoning in Late Medieval Islam

Sally P. Ragep, Institute of Islamic Studies, McGill University, Canada

The subject of sizes and distances of the celestial bodies was an important topic in the Islamic astronomical tradition and, in fact, usually occupied a separate section in most compendia of theoretical astronomy (*hayʾa*). The subject itself can mostly be traced, though by a circuitous route, to Ptolemy's *Planetary Hypotheses*. We can detect divergent attitudes toward Ptolemy's values: some Islamic astronomers defended them while others presented alternative figures. In at least one case, this resulted in a reordering of the planetary positions. By the sixteenth century, this divergence had led to some healthy skepticism about the accuracy, and even relevance, of the genre of "sizes and distances." In addition to providing a brief survey of recent work on sizes and distances, this talk will focus on two contemporaries of Copernicus, ʿAbd al-ʿAlī al-Bīrjāndī and Shams al-Dīn al-Khafrī, and what their discussions of sizes and distances can tell us about this subject in Islamic lands at a time when it was being upended by the Polish astronomer.

Sizes and Distances of the Celestial Bodies in ʿAlī al-Qūshjī's Astronomy: A Historical and Mathematical Analysis

Hasan Umut, Department of History, Boğaziçi University, Turkey

ʿAlī al-Qūshjī (d. 1474) was a prominent astronomer of the fifteenth century affiliated with the Samarqand Observatory. He wrote works in various fields, including theoretical and observational astronomy, mathematics, philosophical theology, and Arabic linguistics. He was involved in observations made in the Observatory and contributed to the compilation of the astronomical handbook/tables, *Zīj-i Ulugh Beg*, one of the most influential ones in its genre produced in the pre-Copernican period. This paper will focus on the sections on the sizes and distances of the celestial bodies in his two theoretical astronomy works, *Risālah dar ʿilm-i hayʾah* in Persian, which was written in Timurid Samarqand around the half of the fifteenth century, and *al-Risāla al-Fatḥiyya* in Arabic, which was compiled in 1473 when Qūshjī was under the Ottoman patronage. A striking point concerning those works is that they adopted different values regarding the sizes and distances of the celestial bodies. More interestingly, the *Fatḥiyya* has at least three versions comprising two different sets of values. This paper aims to offer a historical and mathematical analysis of Qūshjī's parameters and explore his motivations for changing the parameters across his texts and even the versions of the *Fatḥiyya*.

Heliocentric Bias in Ptolemaic Astronomy

Sajjad Nikfahm-Khubravan, University of New Hampshire, USA

Empiricism is the salient feature of Ptolemaic astronomy that makes it the best description of planetary motion before the age of Kepler. The relative accuracy of Ptolemy's analyses means that his results should have some correspondence to what we can call a reality. Now, if we assume that heliocentrism is associated with reality, there should be a correspondence between Ptolemy's geocentric system and any heliocentric one. In fact, there are several instances in Ptolemy's astronomy that can only be explained by conceptualizing a heliocentric system. We call this aspect of Ptolemaic astronomy "heliocentric bias." In this paper, after surveying various cases of heliocentric bias in Ptolemaic astronomy, we focus on two examples. One example is a peculiar pre-thirteenth-century anonymous diagram that appears in a Persian theoretical astronomy (*hayʾa*) work and is related to Ptolemaic models of the longitude of planets. We shall argue that this diagram was drawn by someone who wanted to represent the heliocentric bias in Ptolemaic astronomy. Nevertheless, there is no reason to argue that the anonymous author was committed to any form of heliocentrism. The second example is Quṭb al-Dīn al-Shīrāzī's (d. 710/1311) final latitude theory for the lower planets. Notably, Shīrāzī assumed that the eccentrics of the lower planets always remain in the plane of the ecliptic. Compared to other medieval models, Shīrāzī's model, which is the final result of his extensive study of the motions of planets in latitude, is significantly more analogous to a modern heliocentric system. Nevertheless, nowhere in his astronomy does Shīrāzī come close to a heliocentric concept; still, his model shows another instance of heliocentric bias in Ptolemaic astronomy.

13 September (Wednesday)

PTOLEMAIC AND ALFONSINE HERITAGE

PLENARY LECTURE: 09.00-10.00

MICHAEL H. SHANK, University of Wisconsin-Madison, USA (Professor Emeritus)

The 'Monsters' of Astronomy Before Copernicus: Regiomontanus's Criticisms of Ptolemaic Modeling in the *Defensio Theonis*

More than a century ago, Ludwik Birkenmajer identified the *Epitome of the Almagest* as one of the foundational works on which Copernicus drew. Started by Peuerbach, Regiomontanus's *Epitome* offered a proof-based exposition of Ptolemy's work that occasionally highlighted its problems (e.g., the lunar theory that Birkenmajer noticed). In the last fifty years, ever more of Regiomontanus's criticisms of mainstream astronomy and cosmology have surfaced, increasing the significance of his work for both a re-evaluation of 15th-century Latin astronomy in its own right and the context of Copernicus's revolutionary theory.

This paper presents new evidence of Regiomontanus's fundamental criticisms of the *Almagest*'s planetary theories in his unpublished work. Although the *Epitome* originated in an astronomical controversy, that fact is largely obscured by the work's proposition-and-proof format. This constraint disappears in Regiomontanus's polemical *Defense of Theon against George of Trebizond*. In this book-by-book attack on the latter's commentary on the *Almagest*, Regiomontanus uses language that will later echo in Copernicus: *monstrum* for the lunar theory and many another objectionable view (*intolerabilis*, etc.). Regiomontanus's analyses of planetary theories confirm both his fundamental objections to Ptolemaic devices and his willingness to entertain shocking possibilities. Epicycles, eccentrics, and equants were invented to save uniform motion but fail to do so. Why then not return to concentric spheres even if they must move non-uniformly?

Regiomontanus confronted such problems because, like Copernicus, he sought fundamental consistency between physical and mathematical astronomy. Within that shared vision, however, neither found a solution fully consistent with his own specific principles. Fortunately, Copernicus published anyway. It was his partial solution, not his principles, that endured, proved revolutionary, and moved the debate in a completely new direction.

SESSION 3: 10.00-11.30

Ṭūsī's Couple: How They Reached It

S. Mohammad Mozaffari, University of Science and Technology of China, China

My talk will address two main issues related to Nicolaus Copernicus's astronomical heritage.

(I) In Naṣīr al-Dīn al-Ṭūsī's (1201–1274 CE) *Multaqaṭāt*, the first topic related to Almagest V is a word-by-word quotation of Bīrūnī's (973–1048 CE) *al-Qānūn al-masʿūdī* VII.7.1 on the oval shape of the trajectory of the lunar epicycle's center in the Ptolemaic model. Bīrūnī presents a concrete, straightforward proof that the oval-shaped trajectory is not a perfect ellipse whose foci are the center of the eccentric at syzygies. For him, this problem was an especial case of the general issue of the curling motions (*iltifāf*) of the planets in the Ptolemaic models. Ṭūsī apparently had a keen interest in this topic, as he also mentions it in his three major cosmographical treatises, and curiously extends it to the trajectory of the center of Mercury's epicycle in Ptolemy's model.

What has surprisingly gone unnoticed in the modern scholarship is the direct relation of this topic to the rolling device called today as Ṭūsī's couple. As soon as one digests how the trajectory of the epicycle's center in the lunar model takes its shape, the matter could provide the stimulus for assessing the behavior of the crank mechanism in other conditions, considering the angular velocities and the sizes of its two main components, i.e., the hypocycle and the eccentric. Indeed, the "*simplest situation*" occurs when their radii are equal and the eccentric rotates uniformly. The result is Ṭūsī's couple. Thus, I will argue that, like other new hypotheses created in medieval astronomy, it had a straightforward astronomical origin.

The trajectory problem appears in Latin treatises (e.g., Georg von Peurbach's [1423–1461] *Theoricae novae planetarvm*). However, the matter is not so difficult that any curious student of Ptolemaic astronomy could investigate it for her- or himself, and to deduce its simplest situation, i.e., Ṭūsī's couple. This obviously explains its widespread use in Latin astronomy before and about Copernicus's time. Therefore, I will also argue that Ṭūsī's couple did not need at all be "transmitted" a long way from the Middle East through Byzantium, Italy or Spain to Copernicus; rather, it only needed be "considered" as the absolutely simplest situation of the trajectory problem. What Copernicus asserts in *De revolutionibus* III.4 gives an obvious clue to the direct relation between the two.

(II) I will discuss the most important aspect of Islamic astronomy which has left its hallmark not only in Copernican astronomy, but also on the whole modern astronomy to date. It is a new astronomy which came into birth by some medieval Middle Eastern astronomers in the tenth century and was substantially elaborated and expanded on in a truly significant way by Ibn al-Zarqālluh (d. 1100 CE). It comprises of making new hypotheses on the basis of previously known ones for taking secular changes and periodic variations into account, and, generally speaking, seeing regular patterns within confusing, chaotic, and contradictory empirical results. Since then, it has become a standard in astronomy.

Al-Fārābī and Copernicus: The Prehistory of Osiander's Preface and the Ṭūsī-Couple in *De Revolutionibus*

Johannes Thomann, Institute of Asian and Oriental Studies, University of Zurich, Switzerland

It will be argued that Osiander' preface and the Ṭūsī-pair can be traced back to one and the same source. Ptolemy's model for the latitudinal motion of Venus and Mercury is extremely complicated, and he admitted that it could not be realized in a physical model. In his defense, he argued that simplicity is not the same for God and for man. Al-Fārābī sharply criticized Ptolemy in his commentary on this passage (*Almagest* XIII.2). First, Ptolemy's model contains opposite motions [in one and the same body]. Second, Ptolemy's metaphysical digression is out of place in a mathematical context. The problem should be discussed in physics and metaphysics based on Aristotle's laws of motion. Third, one must return to the study and research in these areas.

Ibn Rushd, who was initially open to Ptolemaic astronomy, later criticized it severely in his commentary on Aristotle's *Metaphysics*. It sounds like an echo of al-Fārābī's formulations when he says that the epicycles are "outside nature," that they contradict Aristotle's laws of motion, and finally that he himself tried to find appropriate solution but failed. It is quite possible that he had read al-Fārābī's commentary when he wrote his own abridged version of the Almagest.

Ibn Rushd's commentary on metaphysics, translated into Latin, with its criticism of Ptolemy, had a great influence on European scholars, who reacted to it in different ways. Albertus Magnus rejected the criticism, while Thomas Aquinas fully adopted it, saying that movements on eccentric and epicyclic circles contradict the established principles of natural science. This last argument was repeated by Andreas Osiander in his preface in *De revolutionibus*, where he wrote that the hypotheses had nothing to do with reality, but were purely mathematical and served only for calculation.

Al-Ṭūsī's paraphrase and commentary, the *Taḥrīr al-Majisṭī* ("Exposition of the Almagest") contains a clear parallel to al-Fārābī's commentary. At the same point in the text, immediately after Ptolemy's metaphysical digression, he begins his critique in almost the same words as al-Fārābī: "This discourse stands outside the [mathematical] discipline and is inadequate in this field." The model, he says, is "incompatible with reality." When al-Fārābī and Ibn Rushd came to this point, they capitulated and expressed only the hope that a fundamentally new approach would solve the problem in the future. Not so al-Ṭūsī. Here he described for the first time in the *Taḥrīr* his famous pair of circles producing a linear oscillation. With this simple device he replaced Ptolemy's unconstructable mechanism for motion in latitude. The same mechanism appeared in *De revolutionibus* III.4. For a long time, Copernicus' dependence on al-Ṭūsī was disputed, but recent studies have documented several possible transmission paths.

The two cases show that the same text provoked different reactions and had opposite consequences in different ways of transmission in *De revolutionibus*: (i) the fundamental doubt about the physical reality of both the Ptolemaic and Copernican systems on the one hand, and (ii) the belief in a technical solution to the shortcomings of the Ptolemaic system by rearranging the orbits on the other.

Homocentric Astronomy and Copernicus

Robert G. Morrison, Bowdoin College, USA

Few who study Copernican astronomy categorically deny that scholarly exchange plays some role in the genesis of Copernicus' theories. Texts of homocentric astronomy, which are devoted to models without eccentrics and epicycles, are an important vector of scholarly exchange during Copernicus' lifetime. I have shown in earlier publications that a text of homocentric astronomy, *The Light of the World*, arrived in the Veneto by the 1600s. This text is written in Judeo-Arabic around 1400 and translated into Hebrew soon thereafter. A scholar, Moses Galeano, with knowledge of the theories of *The Light of the World*, is in Venice between 1497 and 1502. Thus, exchange may occur before the presence of the text.

We have found that *The Light of the World* contains a version of the Ṭūsī Couple, a hypothesis due to Naṣīr al-Dīn al-Ṭūsī (d. 1274) that re-appears in Copernicus' astronomy. As well, *The Light of the World* contains a version of the lunar model of Ibn al-Shāṭir (d. 1375), which appears in Copernicus' work. Of the Islamic theories found in Copernicus' work, the Ṭūsī Couple and Ibn al-Shāṭir's models are the ones that can be most easily modified to cohere with homocentric principles. Unfortunately, most of the chapters on planetary theory from *The Light of the World* have not survived.

Homocentric astronomy is certainly a field in which Galeano and Christian scholars shared an interest. In this presentation, I will focus on the homocentric astronomy of Giovanni Battista Amico (*De motibus*), Alessandro Achillini's (*De orbibus*) and Girolamo Fracastoro (*Homocentrica*). These are Christian scholars in Italy who write on homocentric astronomy in the late 15th and early 16th centuries. I am interested in the authors' statements about the value of predictive accuracy, what the authors mean by the rejection of epicycles, and the ways in which the authors build on earlier work on homocentric astronomy. We will see that texts of homocentric astronomy from the period are a source of theories and discussions that are part of the context of Copernicus' work.

SESSION 4: 12.00-14.00

Without Translators No Latin Astronomy: On the Status Quo of Research on Medieval Translators of Astronomy from Arabic into Latin

Dag Nikolaus Hasse, Julius-Maximilians-Universität Würzburg, Germany

The story of Western European astronomy would have taken a very different course without the enormous work of medieval translators of astronomical texts from Arabic and Greek, such as Gerard of Cremona in Toledo and Michael Scot at the court of Frederick II Hohenstaufen. In this talk I shall survey current research on the work and achievements of translators from Arabic in the twelfth and thirteenth centuries, notably the translators of such influential texts as the Toledan Tables, al-Battānī's *Sabian Handbook*, Ptolemy's *Almagest*, Ibn al-Haytham's *Configuration of the World* and al- Biṭrūjī's *Astronomy*. My focus will be on their intellectual profile: To which extent were these translators scientists in their own right?

Non-Ptolemaic Astronomy in Twelfth-century Latin Europe

Philipp Nothaft, All Souls College, University of Oxford, UK

An essential aspect of the transfer of Graeco-Arabic mathematical astronomy to Latin Europe during the twelfth century was the spread of computational tables in the Ptolemaic tradition, which radically expanded the abilities of their users to track celestial motions and configurations as a function of time. While it may seem natural to assume that the adoption of such tables went hand in hand with the reception of Ptolemaic planetary theory, a closer look at the Latin texts produced during this transitional period reveals a far more complicated picture. Not only did the non-Ptolemaic accounts of planetary motions found in Roman encyclopaedic sources (e.g., Pliny, Macrobius, Martianus Capella) continue to exert a noticeable influence, but attempts to 'reverse engineer' computational tables occasionally led to non-standard or alternative descriptions of the underlying kinematic models. My talk will use neglected or hitherto unknown manuscript material from the twelfth and thirteenth centuries to trace these developments.

Manuscripts Count? A Subjective View of the Alfonsine Tradition with Questions in the End

Matthieu Husson, SYRTE, Observatoire de Paris - Université PSL, CNRS, Sorbonne Université, LNE, France

Manuscripts count for Alfonsine astronomers: much material and intellectual resources were used in making, collecting and keeping them. Manuscripts count for Alfonsine astronomers, in quite literal sense, because they were often their computational tool boxes, the object they would manipulate in their practices. Manuscripts count also for Alfonsine astronomers as concrete embodiment of their competence in understanding celestial phenomenon. Thus manuscripts count for us, they help us produce thick and localised descriptions of their mathematical and more generally astronomical practices, they help us see the growing cultural exposure of the mathematical techniques developed in Alfonsine astronomy by different interconnected communities.

The subjective view I'm proposing is focused on manuscripts. I'll rely on hand full of manuscripts which attracted my attention in the recent years (mainly, Erfut, UB, F. 377 and AM 3134; Paris, BnF, lat. 7281 and lat. 7295A) and illustrate from them some features of Alfonsine astronomy as a discipline that was taught, as craft that was practised, as a place for mathematical invention, as cultural resource in a tormented European landscape. From this quick tour I want to propose some more historiographical questions on mathematics and observation or on stability and innovation as seen from the Alfonsine tradition.

The Equation of Time in the *Epitome Almagesti* and Other Latin *Almagest* Commentaries

Henry Zepeda, Wyoming Catholic College, USA

In both Ptolemy's *Almagest* and Copernicus's *De revolutionibus*, the treatments of the equation of time are relatively brief. Neither includes any kind of a proof or demonstration or a geometrical figure. Few of the Latin commentaries on the *Almagest* cover the equation of time and some of those stay close to their source material. Three of these commentaries, the *Almagesti minor* (ca. 1200), Simon Bredon's *Commentum super Almagestum* (ca. 1340), and Regiomontanus's *Epitome Almagesti* (1461), contain more extensive treatments of the equation of time. Although the *Almagesti minor* generally emphasizes the geometry of the *Almagest* and makes some sections more geometrical, only one of the seven propositions on the equation of time has any sort of geometrical argument or demonstration with a labelled figure. Simon Bredon's treatment is more geometrical, and Regiomontanus's is very much so. Six of his nine propositions include geometrical proofs or explanations. This talk will describe Regiomontanus's treatment of the equation of time, focusing on his use of geometry and especially of figures. It will also compare Regiomontanus's account of the equation of time to those of the earlier commentators on the *Almagest*.

SESSION 5: 15.30-17.00

Examining Astronomical Traditions in the Late Byzantine World (13–15 c.)

Alberto Bardi, Department of the History of Science, Tsinghua University, China

Late Byzantine astronomy saw the merging of several astronomical traditions and engagements with theological and philosophical debates. It is difficult to understand to what extent Byzantine astronomy was innovative, original, or creative. It is likely that new categories are required to assess such a complex period in the history of astronomy. While some advancements in the field have been made, Byzantine astronomy still lacks a proper assessment. Once the clichés about Byzantium being anti-scientific are abandoned, it is tempting to focus on the cross-cultural influences of Byzantine astronomy and on the discrepancy between astrology and astronomy. However, the emergence of certain political discourses is likely the reason behind the absence of developments in late Byzantine astronomy. This paper examines the historical reasons that led Byzantine scholars to translate and compare different sources, how this practice affected their own astronomical activities, and how astronomical activity was related to theologico-philosophical controversies.

The Place of the Alfonsine Tables of Paris in Late Byzantine Astronomy

Anne-Laurence Caudano, University of Winnipeg, Canada

By the late 13th century, Byzantine astronomers were aware that Ptolemaic tables did not yield accurate results and sought to obtain other sets of tables and methods from their neighbours. Their focus turned mostly to Persian astronomy, which many considered more accurate and effective than Ptolemy. Some Byzantine astronomers were also curious about "Latin" tables, however. In the late 14th or early 15th century, the statesman and anti-Latin theologian Demetrios Chrysoloras obtained a canon and a set of the Alfonsine Tables of Paris, which he translated into Greek. This version likely transited through the island of Cyprus (the tables reproduce the radices for Paris and Cyprus), but the computed examples are based on other radices, likely for Constantinople. It does not seem that Byzantine astronomers made much of these tables overall. They are reproduced in only one manuscript, the Vaticanus gr. 1059, a large astronomical compendium belonging to the Patriarchal notary, teacher and astronomer John Chortasmenos, among a variety of Persian and Ptolemaic texts and calculations. Whether this Latin work was included for the purpose of comparison cannot be ascertained, unfortunately. The computed examples reproduced do not feature eclipse calculations, which were typical of Chortasmenos's comparative work with Ptolemaic and Persian tables. That Chrysoloras (or Chortasmenos) sought to make the Alfonsine canon accessible to a Byzantine audience seems clear, in that Theon's *Short Commentary to the Handy Tables*—still a standard textbook for many Byzantine astronomers—was used to establish the Byzantine version of the accompanying canon. Whether or not these tables influenced Byzantine astronomy, they remain a sure trace of a vibrant network of cultural exchanges in the Eastern Mediterranean in the last century of the Empire's existence. They also highlight the increasing discomfort Byzantine astronomers faced when working solely with their Ptolemaic heritage.

The Astronomy of Copernicus and the Image of Copernicus in Hebrew Sources, from the 16th Century to the Present

Y. Tzvi Langermann, Professor Emeritus, Bar Ilan University, Israel

Jews were very active in all phases of astronomy during the medieval period: mathematical theory, observation, construction of instruments, and more. Important texts were translated from Arabic and Latin, and cutting-edge science circulated in original Hebrew texts. However, by the mid-sixteenth century, when Copernicus' writings began to circulate and make their impact, Jewish interest in astronomy had declined greatly. Medieval texts were still copied and read, the writings of Peurbach generated some interest, but with a few exceptions one finds little evidence of any interest in the new developments. *De revolutionibus* was not translated into Hebrew, and references to Copernicus are sparse. Here and there one his heliocentric theory is mentioned, but there really is no deep engagement with Copernicus the astronomer.

On the other hand, Copernicus and what has come to be known as *the* Copernican theory have a non-trivial presence in Hebrew literature, in two very different domains. The great medieval works of Jewish philosophy, written by the likes of Moses Maimonides and Joseph Albo, have been studied incessantly since their publication. These works all contain discussions of astronomical matters, at timers quite technical, but of course all within the framework of

Ptolemaic cosmology. Similarly, matters of timekeeping that depend on astronomy feature in Jewish law. Occasionally modern rabbinic writers, when turning to those passages, will want to examine how the issues play out within a modern framework. Interestingly enough, the "modern" framework—even in the twenty-first century—is not Kepler or classical mechanics, but Copernicus.

At the other end of the spectrum of Hebrew writings, Copernicus is one of the icons of militant atheists—a loud and powerful presence in the Israeli body politic. Copernicus is paraded out along with Galileo and others as heroes in the war of science against religion, often in stunning ignorance of elementary history. For example, Copernicus is said to have rejected the flat-earth theory, as if the sphericity of the earth was not a fundamental principle for Ptolemy and all of his medieval followers. Though we may not know all that much about Copernicus' deep-seated faith, it seems clear enough that he did not consider religion to be foolish nonsense, as some polemicists imply.

14 September (Thursday)

COPERNICAN ASTRONOMY

PLENARY LECTURE: 09.00-10.00

ROBERT S. WESTMAN, University of California San Diego, USA (Professor Emeritus)

Copernicus and the Problem of Astrology: Some Remarks on the State of the Question

One of many vexatious problems in Copernican scholarship is the question of Copernicus's views concerning astrology. Historians have tended to interpret the absence of direct evidence on this matter as evidence that Copernicus either rejected astrology altogether or simply chose to remain silent on the question. In 1990, I associated myself with this majority view in a study of Copernicus's preface to his main work. However, by 1992, my understanding began to change when I first began to study some of the extant astrological prognostications of Domenico Maria da Novara (1454–1504). This shift in my own views also caused me to rethink the chronology of my long-term project on the reception of Copernicus's theory—initially conceived as beginning with the publication of *De revolutionibus* in 1543. Instead, I became persuaded that the extensive prognostication literature of the late 15th and early 16th centuries deserved to be foregrounded together with the importance of Copernicus's experience as a student in Bologna (1496–1500) living and working with that city's leading astrological prognosticator, Domenico Maria da Novara.

In *The Copernican Question* (2011), I proposed the hypothesis that Copernicus's central problem originated in the context of a highly-charged debate about the conceptual foundations of astronomy and astrology which involved the uncertain order of Venus and Mercury with respect to the Sun. This debate commenced in 1496 with the posthumous publication of Giovanni Pico della Mirandola's *Disputations against Divinatory Astrology*—just a month or two before Copernicus arrived in Bologna to commence his legal studies. And Pico's learned, scholarly study quickly acquired an overtly political character when, in 1497, the Dominican friar Girolamo Savonarola (1452–1498) denounced astrology and its practitioners in a vernacular work based explicitly upon Pico's *Disputations* but directed to a much wider audience.

Early critical reactions to this reconstruction resulted in an extensive exchange of views in 2012–2013. In December, 2013, I presented still further evidence for my reconstruction in a lecture titled *Copernicus and the Astrologers*, originally delivered at the Dibner Library in Washington, D.C and published in 2016. Since then, still further interesting questions have been raised by other scholars and it is to those that the principal part of my presentation will be directed.

SESSION 6: 10.00-11.30

Copernicus and the Stams Astronomical Table of 1428

Richard L. Kremer, Professor Emeritus of History, Dartmouth College, USA

Although mentioned by Zinner in 1956, the Stams astronomical table has been carefully examined only once, by Poulle in his 1980 survey of Ptolemaic planetary equatoria. Comprised of three one-meter square panels of wood covered in parchment, this table presents moving, two-dimensional models for the planets and Moon, presenting for Saturn, Jupiter and Venus double epicycles and eccentrics without equants. No solar model is included. An inscription dates this *opus sperarum completum* to 1428 and attributes it to Rudolf Medici, a master and canon in Augsburg. Rudolf appears in records of the Augsburg archdiocese but is otherwise unknown; no other works have been attributed to him. I have found a short canon for the Stams table, but like most canons it simply describes how to use the models but does not explain why the equant is replaced by a double epicycle.

Since double-epicycle planetary models are unknown in medieval Latin astronomy (several 15c sources do propose double epicycles to keep the same lunar surface facing the Earth) before their appearance in Copernicus's 1514 *Commentariolus*, the Stams table seems exceedingly curious in the era of Alfonsine astronomy, when innovators focused on "user-friendly" tabular formats and not on planetary theory. Significantly, the Saturn-Jupiter panel can also be viewed as a heliocentric arrangement (which would bring the Sun into the table) not unlike al-Shatir's cosmology from the 1370s. No surviving sources support this interpretation of the Stams Table. But thinking about this equatoria might be relevant to previous and continuing historiographical discussions about Copernicus's "originality" and earlier non-Ptolemaic models.

The Motivation and Trajectory of Copernicus's Early 'Homocentric' Planetary 'Models'

André Goddu, Emeritus Professor of Astronomy and Physics, Stonehill College, USA

In the *Commentariolus* Copernicus did not use the term 'homocentric'. The planetary 'models' are concentric, but not with the true Sun. Unable to dispense with the eccentricity of Earth's annual motion around the Sun, Copernicus proposed a qualified 'homocentrism', according to which the primary planetary epicycles were centered on the center of Earth's annual path, the eccentric or mean Sun. Accordingly, the system should properly be called "homo-eccentric" and, for the sake of completeness, "homo-eccentric, by-epicyclic." The essay explores Copernicus's motivation for proposing such a mechanism, and it reflects on the 'trajectory' of his early planetary cosmology.

Celio Calcagnini's Philosophical Defense of the Motion of the Earth (ca. 1518)

Pietro Daniel Omodeo, Ca' Foscari University of Venice, Italy

Around 1518, the Ferrara humanist Celio Calcagnini (1479–1541) wrote an original defense of Earth's motion, *Quod caelum stet, terra moveatur vel de* *perenni motu terrae* (The Heavens Stand, the Earth Moves, or the Perennial Motion of the Earth). It was a short but complex philosophical treatise, written in a sophisticated style, on a topic of undoubted interest to the history of cosmology. It is one of the earliest documents attesting to the Renaissance circulation of geokinetic conceptions, in the very years when the revolutionary ideas of Copernicus started to circulate and the *De revolutionibus orbium coelestium* was taking shape. Yet, Calcagnini's text has not received adequate consideration in the history of science, apart from a few exceptions. This communication is devoted to this lesser known intellectual figure. It stems from a collaboration with Alberto Bardi aimed to offer the first modern translation of *Quod caelum stet*. I will discuss the cultural context from which Calcagnini's defense of terrestrial motion emerged. It especially relied on natural and epistemological considerations within the framework of an eclectic humanistic philosophy, influenced by skepticism and Platonism. Calcagnini discussed at length the limits of our cognitive faculties and argued for the need that reason moves beyond immediate sensible appearance. He then argued for the plausibility of the Earth's motion against common sense, on the basis of a series of natural arguments. I see this treatise as an important witness of the formation of cosmology, although Calcagnini remained vague concerning the celestial motions he actually attributed to the Earth. I will also discuss possible connections with Copernicus and his work.

SESSION 7: 12.00-13.00

Copernicus' Heliograph in Olsztyn

Gerd Graßhoff, Humboldt University of Berlin, Berlin Institute for the Foundation of Learning and Data, Germany

Around 1517 Nicolaus Copernicus drew a grid of lines on a panel above the door to his rooms at Olsztyn Castle, then in the Bishopric of Warmia. Although his design has long been regarded as a kind of reflecting vertical sundial, the exact astronomical designation of the lines and the measurement techniques involved have been the subject of scholarly debate. Copernicus did not refer to his new observational methods in his main work, *De revolutionibus*. In 2018, a data analysis of a 3D model of the tablet finally solved the mystery: Copernicus created a new type of measuring device – a heliograph with a non-local reference meridian – to accurately measure the ecliptic longitudes of the Sun. In this talk I will propose why Copernicus chose a non-local meridian for the heliograph: measuring the Sun's motion relative to the meridian of Nuremberg would directly link his data to the long-term observing program initiated by Regiomontanus, Walther and curated by Schöner.

Copernicus's Astrological Expertise

David Juste, Ptolemaeus Arabus et Latinus – Bayerische Akademie der Wissenschaften, Germany

This paper revisits the astrological annotations found in the margins of Copernicus's personal copy of Haly Abenragel's *De iudiciis astrorum* (*On the Judgements of the Stars*).

15 September (Friday)

EARLY RECEPTION

SESSION 8: 08.30-10.30

The Keplerian Interpretation of Aristarchus's Copernicanism

Christián Carlos Carman, National University of Quilmes, Argentina

It is well known that heliocentrism was proposed in ancient times, at least by Aristarchus of Samos. Given that ancient astronomers were perfectly capable of understanding the significant advantages of heliocentrism over geocentrism—i.e., that it offers a non-ad hoc explanation of the retrograde motion of the planets and unequivocally orders all the planets while allowing one to know their relative distances—it seems difficult to explain why Aristarchus' heliocentrism did not

triumph over geocentrism or even offer significant competition to it before Copernicus. Usually, scholars refer to explanations of sociological character, such as the authority of Ptolemy or the influence of religion. In 2018, I offered a different reason: Aristarchus' heliocentrism was significantly different from Copernican heliocentrism: while Copernicus asserted that the Earth and all the planets revolved around the Sun, Aristarchus says nothing about the planets. If only the Earth revolved around the Sun (setting aside what happened with the other planets), then the advantages of heliocentrism vanish. My main argument was that nobody before Copernicus interpreted Aristarchus' heliocentrism as described in Archimedes' *Arenarius* as referring to the planets and almost everyone did that after Copernicus. I have recently found, however, an interesting objection to this proposal in the writings of Johannes Kepler. In his *Apologia pro Tychone contra Ursum*, Kepler affirms that "by his discoveries, Copernicus made it possible for us to understand the report of … Archimedes about Aristarchus", i.e., that after Copernicus, and thanks to his heliocentrism, he realized that Aristarchus had proposed the same. In this talk, I will discuss this Keplerian interpretation.

'And here appeareth the lawfull use of Astrologie': On the Distances and Sizes of the Planets in the Heliocentric Cosmos as Discussed in London in the Year 1603

Jarosław Włodarczyk, Institute for the History of Science, Polish Academy of Sciences, Poland

Edward Gresham (1565–1613) was a physician and almanac maker based in London. He was one of the early adherents of Copernican theory. The most comprehensive account of his views can be found in the manuscript treatise entitled *Astrostereon or the Discourse of the Falling of the Planet* written in September 1603. In this treatise Gresham insisted on observing planetary occultations to see that the planets are solid and opaque. Independently from Johannes Kepler, Gresham became a forerunner of lunar astronomy which he used, similarly to Kepler, to demonstrate the fragility of the arguments for the geocentric system. Gresham discussed also the distances and sizes of the planets in the heliocentric cosmos. He had two reasons to offer this discussion. Firstly, he wished to expose the absurdity of the rumor spreading in London, ascribed to him and to John Dee, about the expected fall of the planet upon the Earth. Secondly, Gresham strived to introduce a new architecture of cosmos which allowed for a reformed way of assessing the influence of the planets on each other and on the Earth. In this paper I intend to demonstrate how the system of the distances and sizes of the planets proposed by Gresham appears to be a combination of Copernican astronomy and of the ideas to be found in Jofrancus Offusius's *De divina astrorum facultate* (1570). Additionally, I shall consider the coherence of Gresham's system, particularly with regard to apparent diameters of the planets which he postulated.

Reframing Copernicus' Earth–Moon *cognatio*: From Similarities to Evidence in Favor of Heliocentrism

Natacha Fabbri, Museo Galileo. Istituto e Museo di Storia della Scienza, Italy

The Earth–Moon *maxima cognatio* mentioned in *De revolutionibus* (Book I, Chapter 10) and its role in the development and reception of the heliocentric theory were examined by many 16th and 17th-century astronomers and philosophers. The paper will compare and contrast the different interpretations of this *cognatio* that can be found in Reinhold, Maestlin, Gilbert, Stevin, Galileo, and Kepler, among others, as well in the debates over new stars, comets, and sunspots. I will also analyze how those ontological and/or morphological similarities had been intertwined with astronomical and philosophical arguments aiming to provide strong evidence in favor of the movement of the Earth.

Copernicans in Their Own Way: Struggling with Heliocentrism within the Academy of the Linceans (1603–1630)

Federica Favino, Sapienza University, Italy

On 24 March 1616, the members of the Academy of the Linceans, gathered in the usual seat of Palazzo Cesi 'a la Mashera d'Oro', decided to expel the mathematician Luca Valerio for having broken academic solidarity. Valerio, in fact, had refused to participate in that meeting organized in support of Galileo, just targeted by the anti-Copernican decree. Yet, recent scholarship has highlighted that not all the Linceans agreed on the Copernican system (which they mostly knew through their fellow Galileo), since its reception even among them was strongly conditioned by theological considerations, but even more by their individual cultural background and their ability to understand a revolutionary system of the world. My contribution aims at exploring these different positions, making them resound with the debates on heliocentrism that Galileo's trip to Rome in 1611 had generated within the cloisters and among 'public opinion'.

SESSION 9: 11.00-12.30

The Initial Reception of Copernicus in Spain: From Jerónimo de Chaves and Jerónimo Muñoz to Diego de Mesa and Juan Cedillo Díaz

Miguel Ángel Granada, University of Barcelona, Spain

The standard narrative of the reception of Copernicus in Spain between the publication of *De revolutionibus* in 1543 and the condemnation of Galileo in 1633 is often limited to the authorized instruction of heliocentrism at the University of Salamanca by the 1561 statutes and the defense of the compatibility of the motion of the Earth with Scripture by Diego de Zúñiga in his *In Job commentaria* (Toledo, 1584). This has recently been extended to the adoption of Copernican cosmology by Juan Cedillo Díaz in his manuscript translation of the first three books of the *De revolutionibus*, carried out in the years before and after the first condemnation in 1616. In addition to clarifying the precise meaning of these views, we will examine other positions that are not sufficiently well known: Jerónimo de Chaves' critique in his commented Castilian edition of Sacrobosco's *Sphaera* (Seville, 1545), as well as the criticism by Jerónimo Muñoz and his disciple Diego Pérez de Mesa, who, in manuscript works, rejected heliocentrism and the motion of the Earth from a cosmology of a fluid heaven of air, which excluded the double motion of the planets in opposite directions, postulating instead a unique planetary motion from east to west that decreased in speed from Saturn and followed a trajectory along spiral lines.

Copernicus in Astrological Works: Spanish Early Modern Authors

Tayra MC Lanuza-Navarro, Ca Foscari Università di Venezia, Italy / Universitat Pompeu Fabra Barcelona, Spain

A high number of works of astrological content were circulating in Spain during the 16th and 17th centuries, among which some mentioned the *De revolutionibus* or discussed issues related to Copernicanism. The study of these sources increase our understanding of the uses astrologers made of Copernicus' ideas and/or name in this period. This paper discusses astrological sources of different nature: popular prognostications about comets, the works by cosmographers entitled chronography and repertories of times, and astrological works aimed for teaching. Astrologers, established certain kinds of relationships between their discipline and Copernican issues, and the aim of this research is to explore how those astrological authors linked their astrology to Copernicus or his work.

Copernicus Biographies and Biographical Essays as Part of the Culture of Remembrance

Andreas Kühne, Ludwig-Maximilians-Universität, Munich, Germany

By and large, most Copernicus biographies have been written in Poland and Germany. However, in the periods between 1550–1800, 1800–1870 and 1871–1933 in both countries these biographies were characterized by differing emphases and tendencies, even as they were marked by fundamental continuities, no matter how the territorial borders in this part of Europe shifted.

After 1933, there were massive attempts in Germany to instrumentalize the Copernicus topic for the purposes of nationalistic ideology and science policy. A further phase with clearly different goals in the fields of ideologies and science policy covers the time from 1946 to 1989.

Based on meaningful examples drawn from selected biographies the paper will deal with continuities and changing tensions between science, ideology, science policy, and the public.

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